



ENERDAY conference 2021

Renewable Energy Targets and the Storage Cycling Trap

Unintended Effects and Implications for Power Sector Modeling

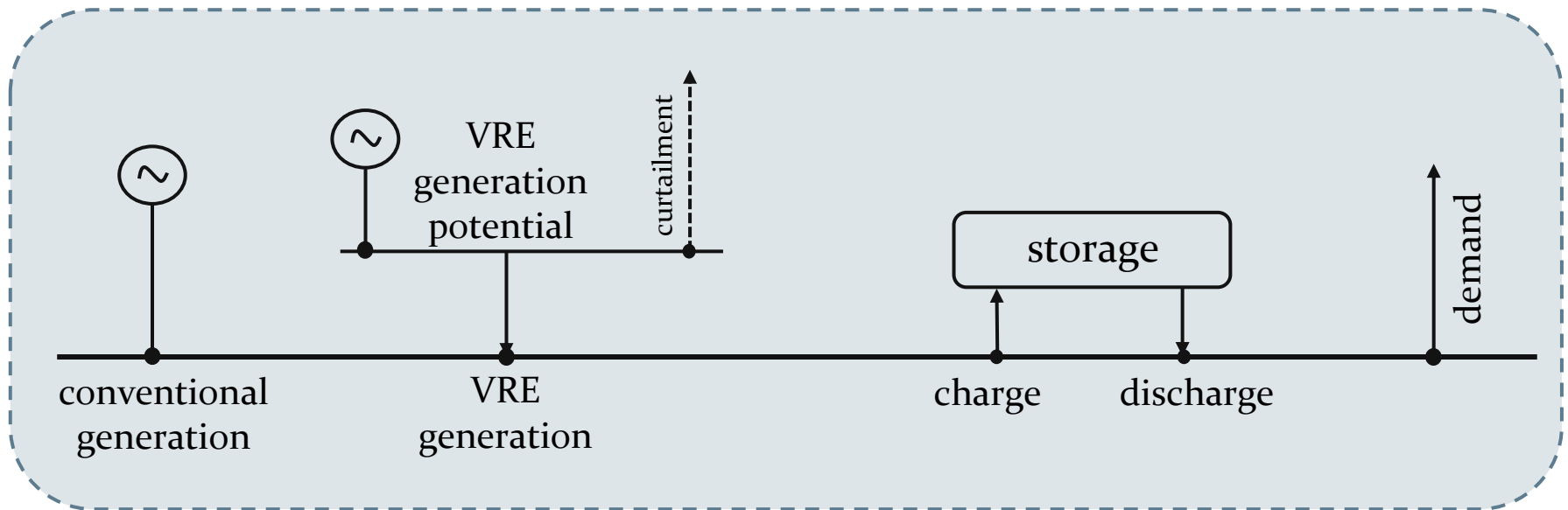
Martin Kittel and Wolf-Peter Schill

Berlin, April 9

Agenda

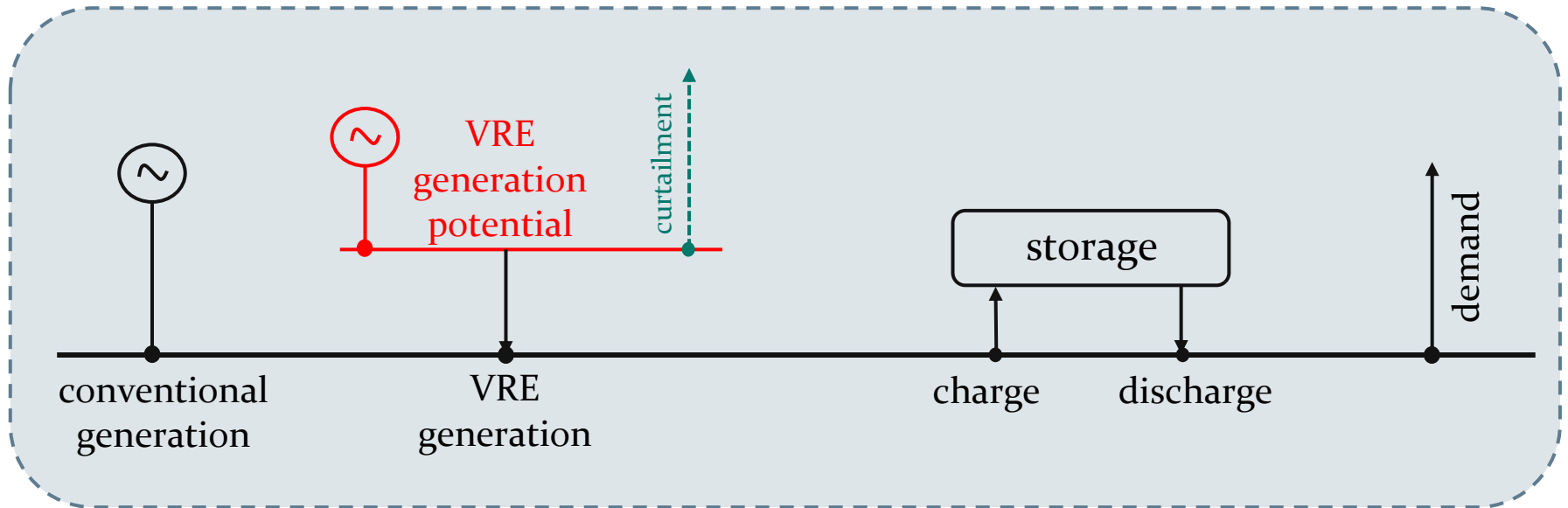
1. Problem setting
2. Research question
3. Methods
4. Key results
5. Conclusion

Simplified power sector



Source: own illustration

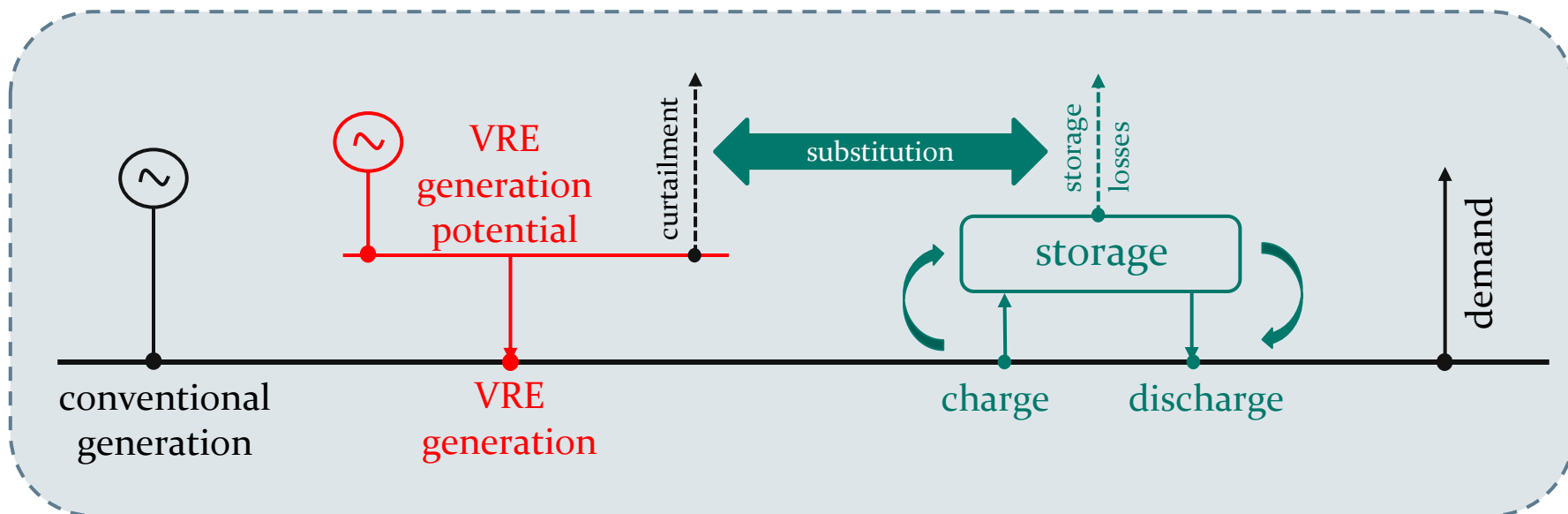
Expected outcome: some curtailment of renewable excess (or surplus) electricity (cp. Zerrahn et al. (2018))



Source: own illustration

Imposition of minimum RES share ϕ causes unintended effects

$$\sum Generation^{RES} \geq \phi \sum Demand$$



Source: own illustration

- Unintended storage cycling \equiv simultaneous, thus excessive, charging and discharging of the same storage unit

Research Questions

1. What are possible minimum RES share constraint formulations?
2. What is the effect of unintended storage cycling on model outcomes?
 - On storage: dispatch and investment
 - On remaining system elements: dispatch and investment, total system cost, prices
3. What are drivers of unintended storage cycling?
4. What are solution strategies?

Relevance

- RES targets commonly used in climate policy, e.g. in DE (65% in electricity sector by 2030) and USA (100% by 2035)
- Numerical models used for research & policy consulting → unintended storage cycling potentially distorts model outcomes, thus also policy recommendations

Model	renewable share in demand	conventional	renewable share in generation	conventional	consideration storage losses	CO ₂ budget	CO ₂ price
Calliope	x	x	x	x	partial	x	x
E2M2	x				complete	x	x
DIETER		x			complete	x	x
ENTIGRIS	x	x			no		x
LIMES-EU	x		x		partial	x	x
oemof	x	x			no	x	x
PyPSA	x		x		no	x	x
REMix	x		x		partial	x	x
EMMA	x				no		
anyMOD						x	x
dynELMOD						x	x
ELTRAMOD						x	x
ISAaR						x	x

- Storage cycling has not yet been covered in literature*

Source: own illustration

*to the best of our knowledge

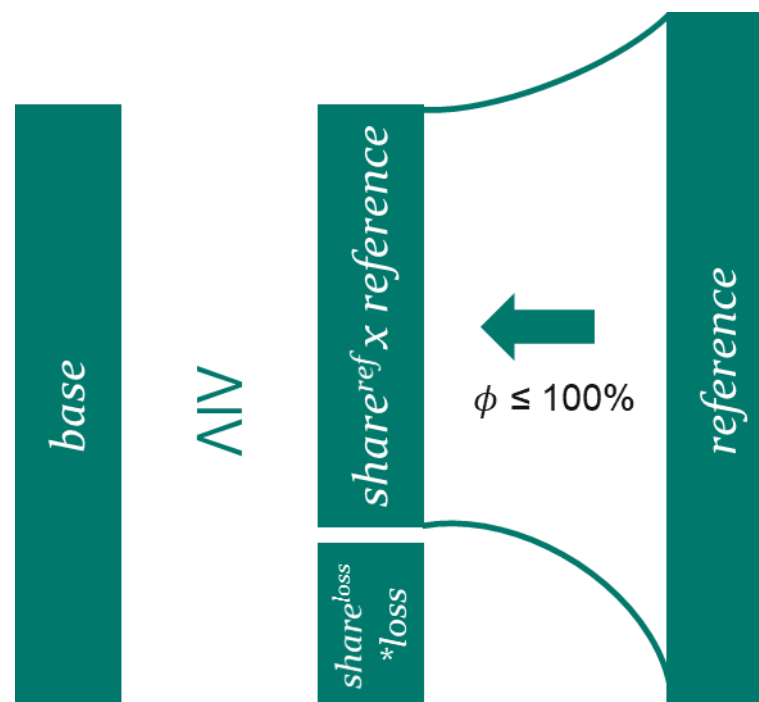
Work in progress!

Investigated constraints

1. Minimum RES share in total demand
2. Minimum RES share in total generation
3. Maximum conventional share in total demand
4. Maximum conventional share in total generation

Variations per constraint

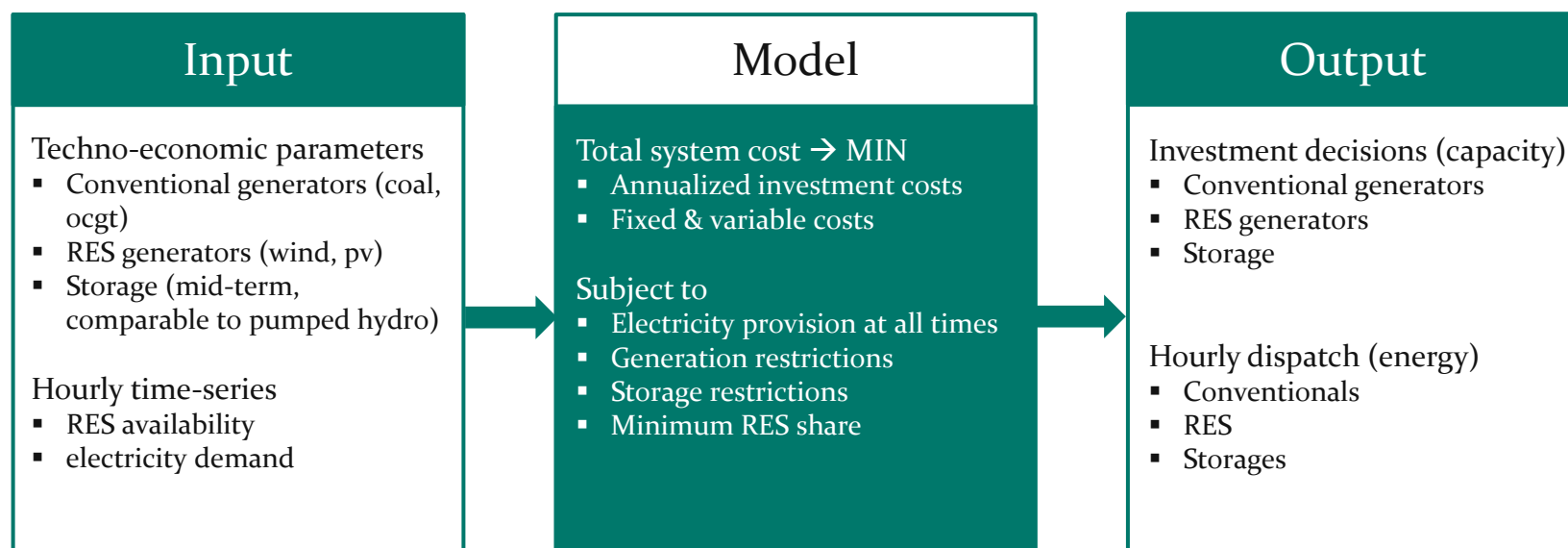
- a) No SLCR: Storage losses covered by conventionals
- b) Proportionate SLCR: Storage losses partially covered by RES and conventionals
- c) Complete SLCR: Storage losses completely covered by RES



Source: own illustration

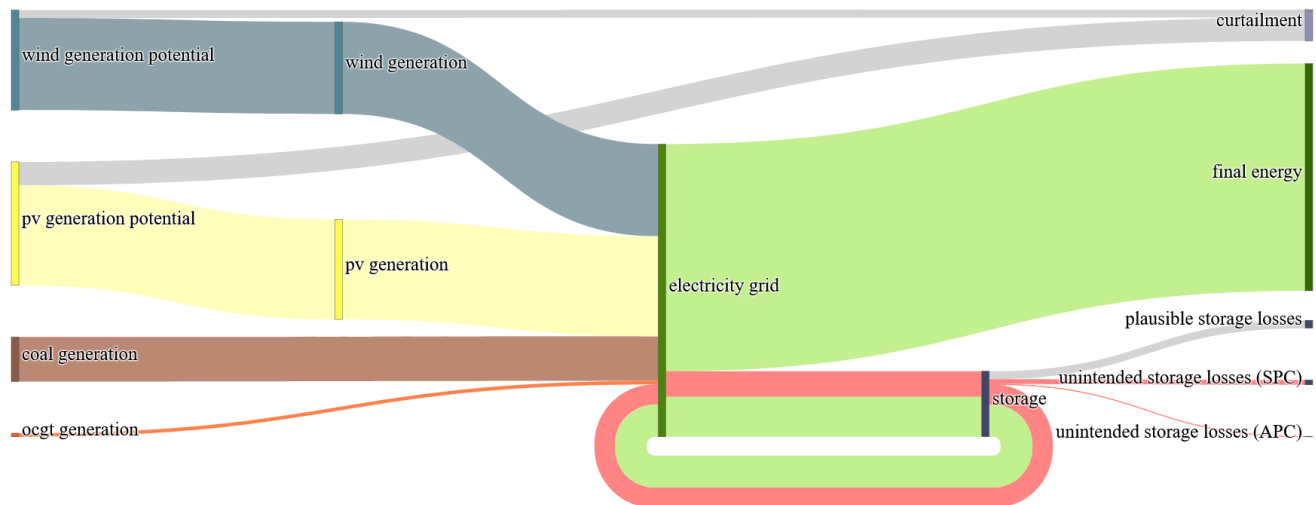
Stylized numerical power sector model → reduced DIETER (Zerrahn et al., 2017)

- Used in Zerrahn et al. (2018)
- Implemented in DIETERpy (Gaete et al., 2020)
- Linear, partial equilibrium model
- One region („copper-plate“)
- 8760 h of target year
- Power sector only
- Annual demand = 504 TWh
- Minimum RES share $\phi = 80\%$

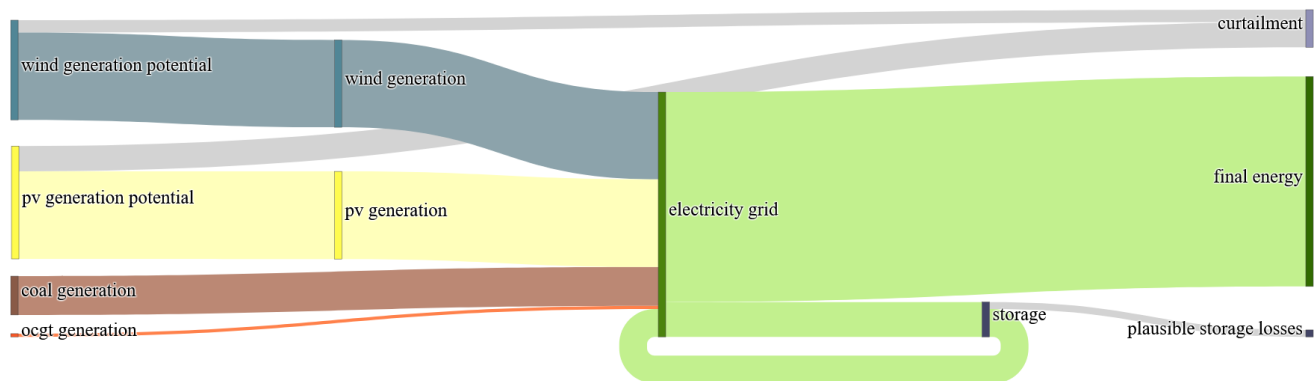


Source: own illustration

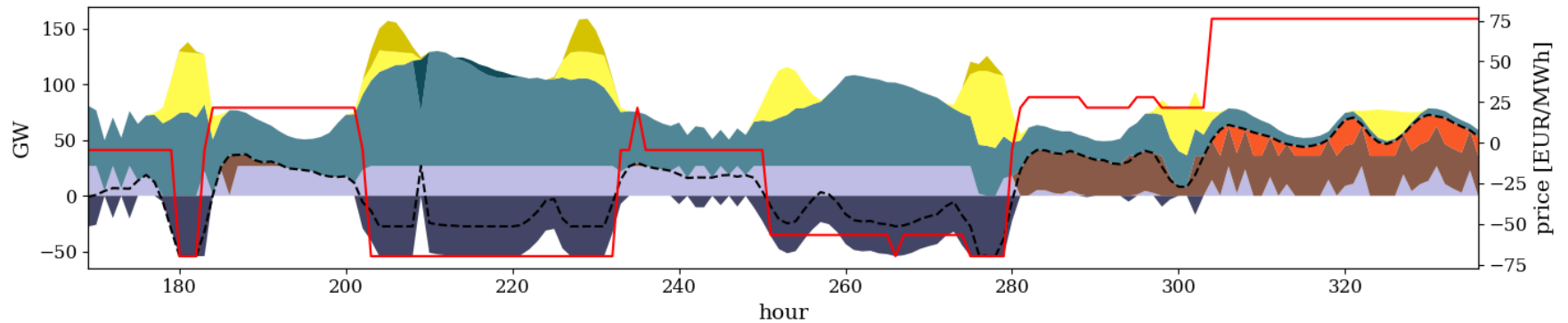
Unintended storage cycling



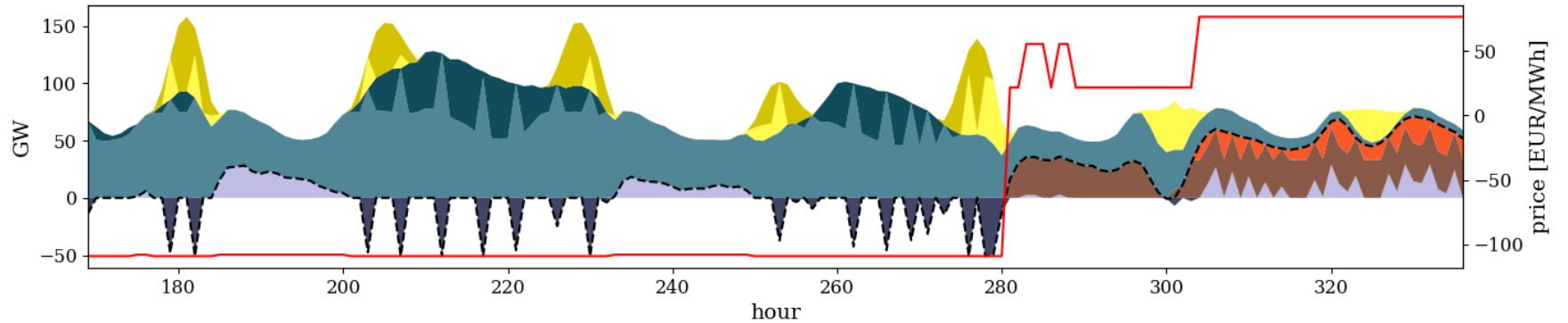
No unintended storage cycling



Unintended storage cycling



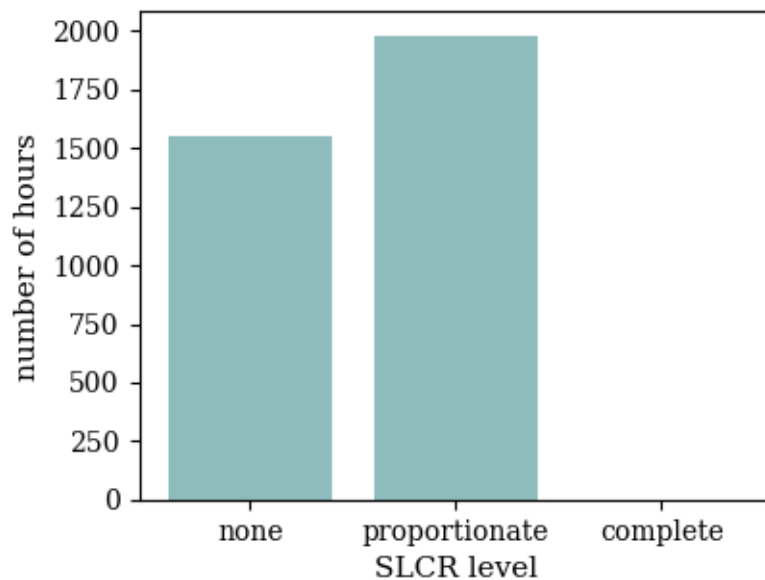
No unintended storage cycling



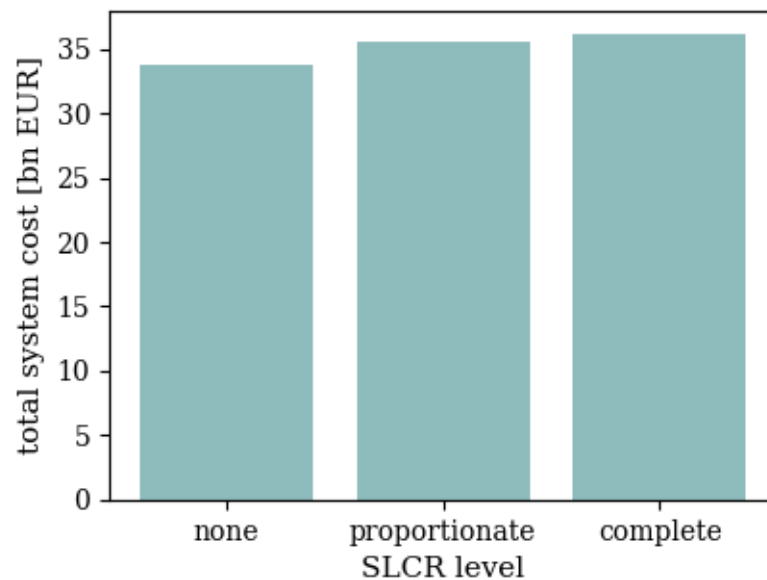
storage charge
 coal
 wind
 pv
 residual load
 storage discharge
 oagt
 wind curtailment
 pv curtailment
 electricity price

Source: own illustration

Unintended storage cycling occurrences



Total system costs

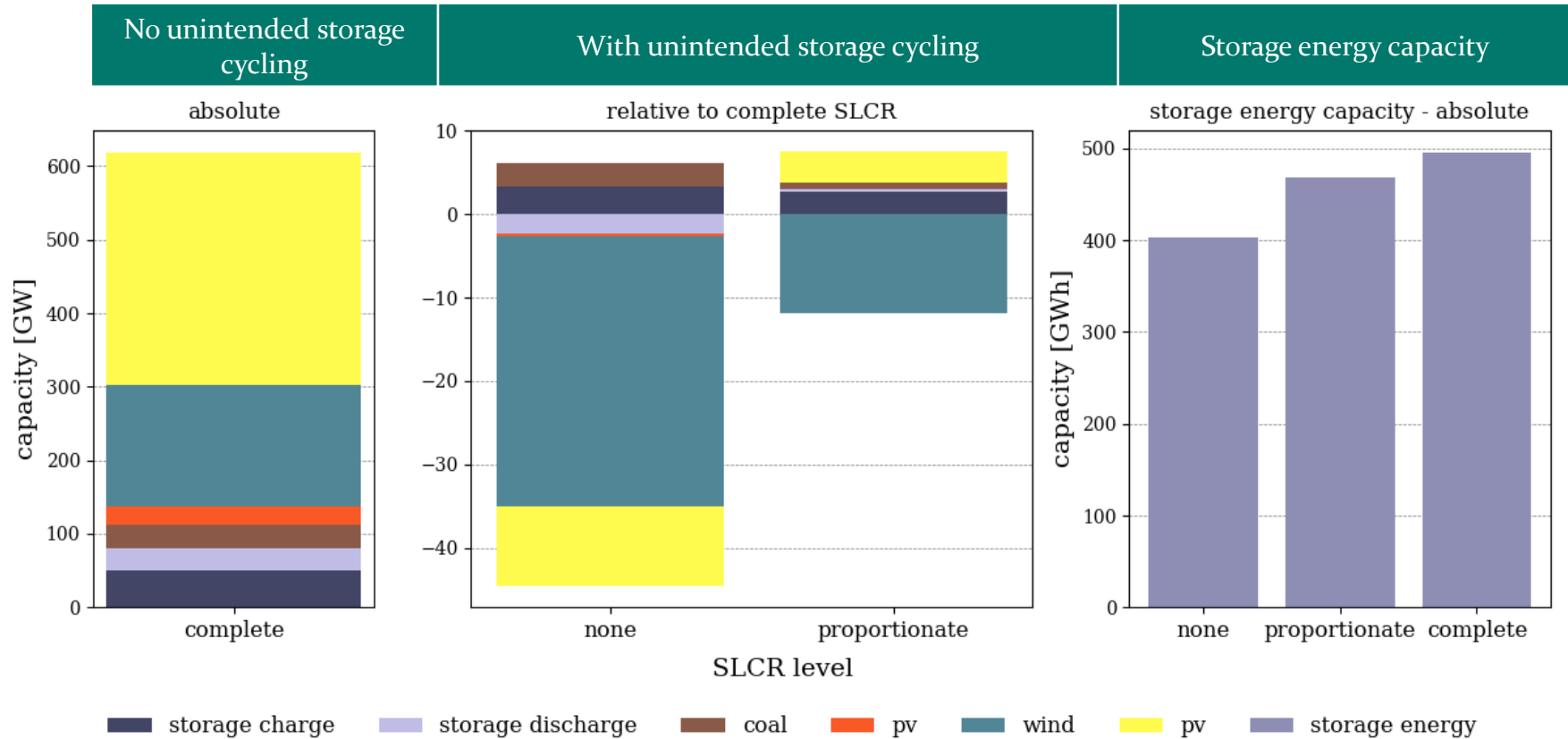


- SLCR: Storage Losses Covered by Renewables
- Models with complete SLCR by RES avoid unintended storage cycling

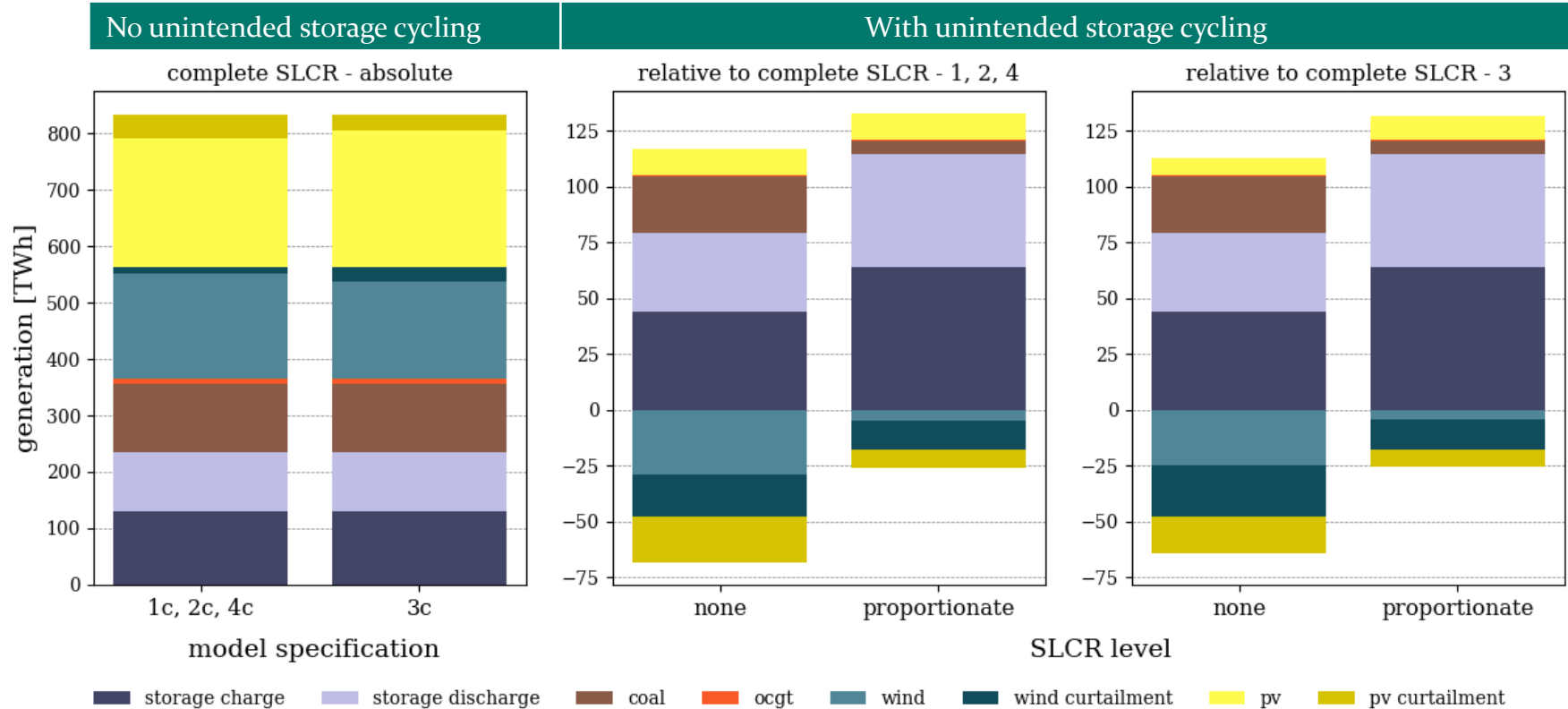
Source: own illustration

4.4

Impact on optimal investment decisions

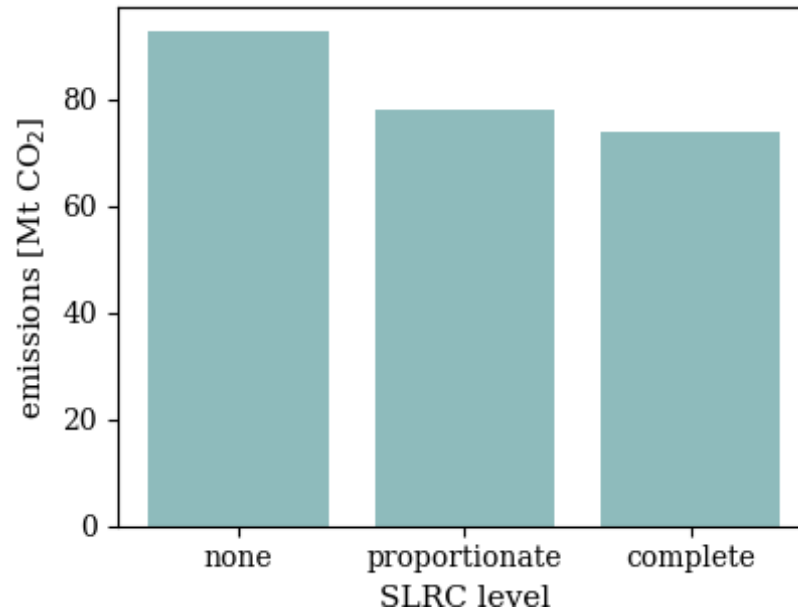


SLCR: Storage Losses Covered by Renewables



SLCR: Storage Losses Covered by Renewables

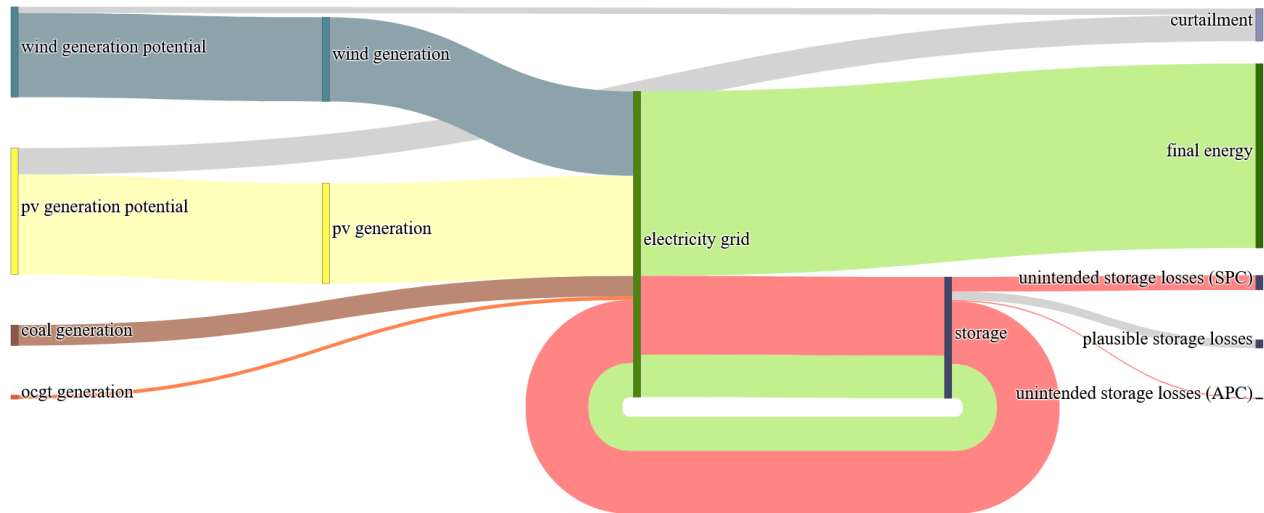
Increased generation from coal → rise in emissions



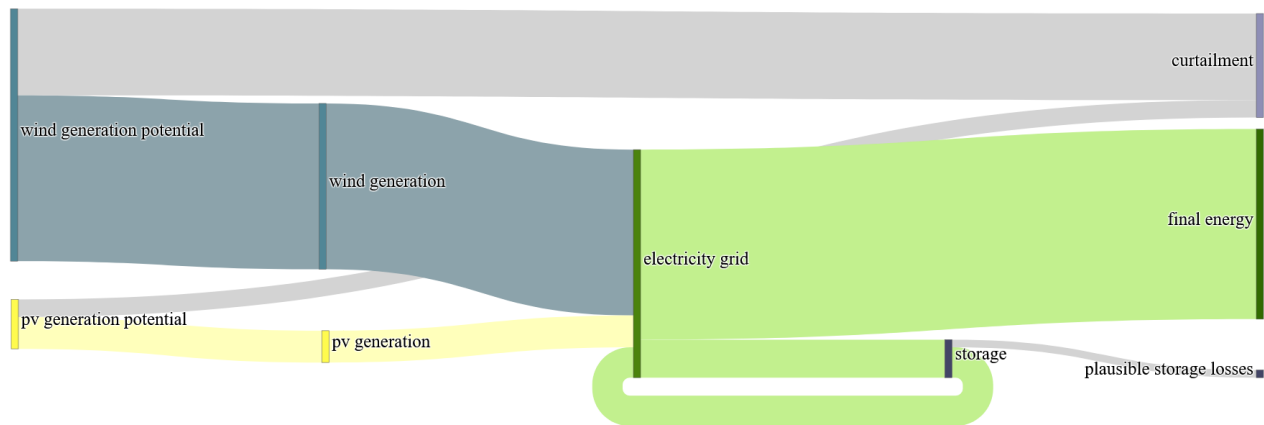
SLCR: Storage Losses Covered by Renewables

Source: own illustration

Unintended storage cycling



No unintended storage cycling



Solution strategies

- Complete coverage of storage losses by RES prevents unintended storage cycling
 - Possible alternatives
 - Theoretical RES generation potential → imprecise, underachievement
 - CO₂ budget, CO₂ price
- binding RES policy targets cannot be modeled



Summary

- Unintended storage cycling has significant effect on model outcomes → distortion of policy recommendation
- Implementation matters → complete storage losses in RES constraint is a necessity for cost-optimal decarbonization pathways

Zerrahn, Alexander, and Wolf-Peter Schill. "Long-run power storage requirements for high shares of renewables: review and a new model." *Renewable and Sustainable Energy Reviews* 79 (2017): 1518-1534.

Zerrahn, Alexander, Wolf-Peter Schill, and Claudia Kemfert. "On the economics of electrical storage for variable renewable energy sources." *European Economic Review* 108 (2018): 259-279.

Gaete-Morales, C., Kittel, M., Roth, A., Schill, W. P., & Zerrahn, A. (2020). DIETERpy: a Python framework for The Dispatch and Investment Evaluation Tool with Endogenous Renewables. *arXiv preprint arXiv:2010.00883*.

Thank you for your attention!



**DIW Berlin — German Institute
For Economic Research e.V.**
Mohrenstraße 58, 10117 Berlin
www.diw.de

Martin Kittel
mkittel@diw.de
